

Gamma Spectrometric Techniques in Radiation Monitoring at Borders - Importance of Spectrum Modeling

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The Director General of the IAEA, Dr. ElBaradei on the Global Threat on Nuclear Terrorism

- ❑ Terrorists are unconcerned about exposing themselves to radiation could easily conceal a source in a truck or a suitcase.



"The danger of handling powerful radioactive sources can no longer be seen as an effective deterrent,

which dramatically changes previous assumptions,"

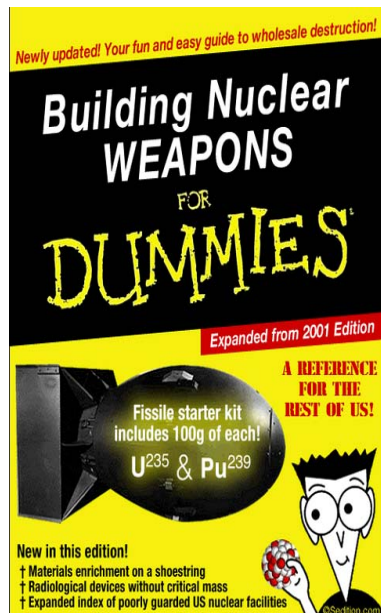
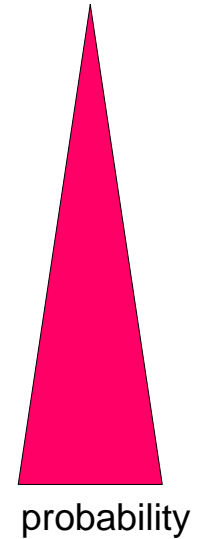
- ❑ **..."security of nuclear and other radioactive material has taken on dramatically heightened [in our work] significance in recent years..."**



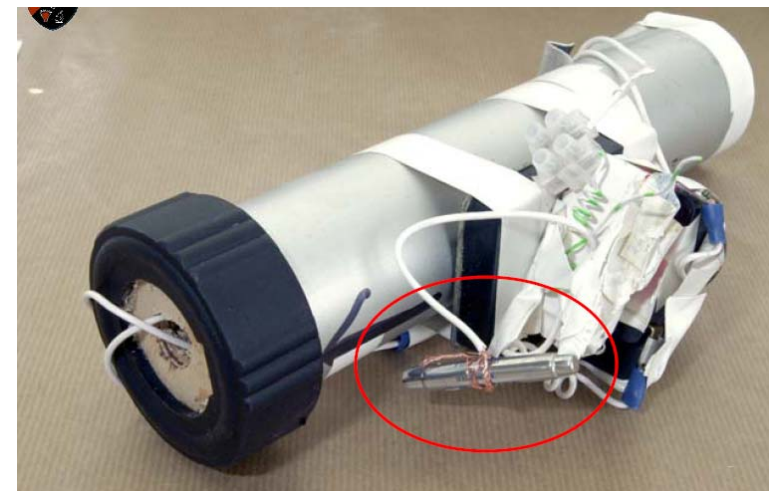


Risk = Probability x Severity

- Theft of a nuclear weapon
- Acquisition of nuclear material for the construction of a nuclear explosive device
- Attack on, sabotage of, a nuclear facility or transport of spent fuel
- The malicious use of radioactive sources, radiological dispersion devices (RDDs) or radiation exposure device (REDs)



How to prevent?



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Strong sources can be detected from distance!

Detection and Response at the Border in a Nutshell

- Large vehicle monitor alarms (step 1)
- Stop and confirmation of the alarm
- Localization and secondary inspection (2), e.g.
 - Second pass
 - Search with Radionuclide Identification Device (RID)
 - Assess dose rate (safety)
 - Categorization of the source to determine response

- Natural
- Medical
- Industrial
- Nuclear

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Manual search and ID cause delay

Automated Radiation Detection Combined with automated ID is more Effective but also More Expensive

- Advanced Spectroscopic Portal (ASP), US 2004
- Spectrometric Radiation Portal Monitor (SRPM), for pedestrians, IAEA 2004, US 2008
- Spectrometric Personal Radiation Detector (SPRD)
- Backpack based Spectrometric Radiation Search Device (RSD)
- Human Portable Radiation Detection System (HPRDS) - a new generation of RIDs

Security costs money

Truck and Container Monitoring, Using RPM or ASP

- High throughput BCPs in the US (up to several 1000 trucks per day)
- Radiation check done on the fly (e.g., at 8 km/h)
- Presently gross gamma detectors are used
- If alarm, stop, performance of source search and categorization with RID required (second. insp.)
- Advanced Spectroscopic Portals (ASP) suggested by DHS, DNDO (US, 2004)
- Gamma spectrometry and ID combined

The ASP Concept

- Plastic scintillator of RPM replaced by spectrometric NaI, (HPGe)
- Adding of stabilized gamma spectra of up to 24 NaI detectors (sensitivity)
- Fast identification software on PC to perform ID in seconds
- However:
 - Large data volume
 - ID of shielded sources is difficult
 - High price



Conventional monitor uses plastic scintillator

ASP type detector with NaI



ASP Deployment Has Been Delayed...



ASP test runs at the Nevada test site in the US

- 2004, two broad agency announcements in the US
- 2005, first tests at the Nevada test site, DNDO suggests procurement
- 2006 contracts awarded by DNDO to 3 companies
- 2006 and beyond: GAO objections... delays
- 2009 no decision yet
- Certification expected late 2009

Radiation Monitoring of Pedestrians & Luggage

- Present procedure
 - Alarm of a pedestrian portal monitor with a gross gamma detector
 - Stop
 - Manual categorization with RID*
 - Localization (G/N)
 - Gamma dose rate
 - Neutron countrate
 - Isotope/category
 - Decision delayed
 - ✓ Intrusive
 - ✓ High workload
 - ✓ Reduced throughput

Radiation Pedestrian Monitor

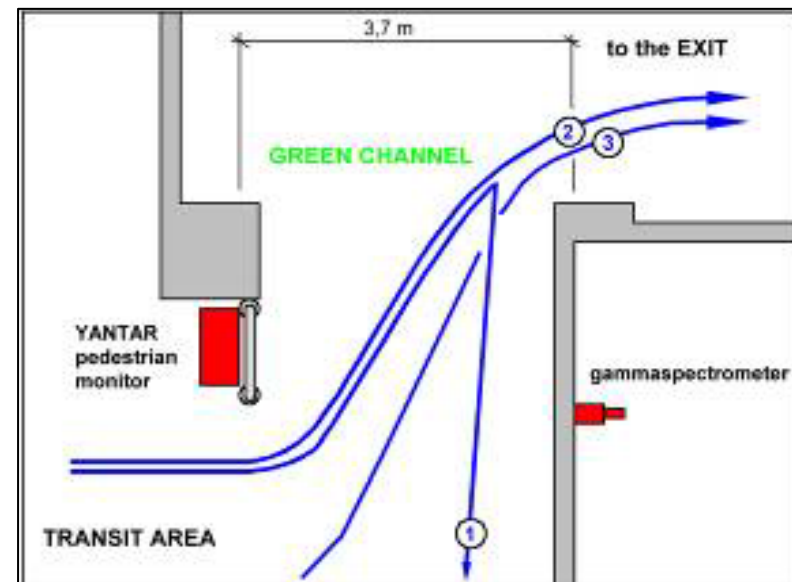
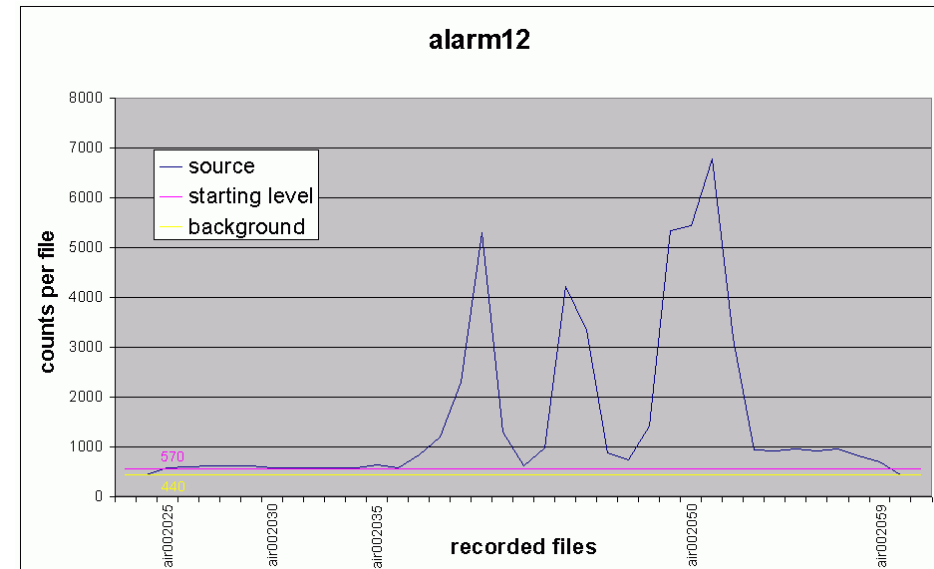
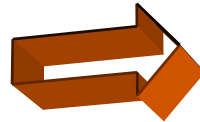


New: Spectrometric Systems for Pedestrians and Luggage

- 2004 suggestion at the IAEA to develop spectrometric radiation portal monitoring system (SRPM), e.g., for airports (high throughput)
- Better chance of success as ASP, since
 - Passengers pass through metal detectors
 - Luggage is X rayed
 - Detection of shielding
 - But in 1 in about 5000 to 10000 persons may have medical treatment (radiation alarm)
- First feasibility study at the Vienna International Airport in 2004/2005 was successful
- 2009, several companies offer SRPMs

First Field Test at the Vienna International Airport (2004/2005)

- 241 days of operation
 - 163 events
 - 154 Medical
 - 3 NORM
 - 5 not identified

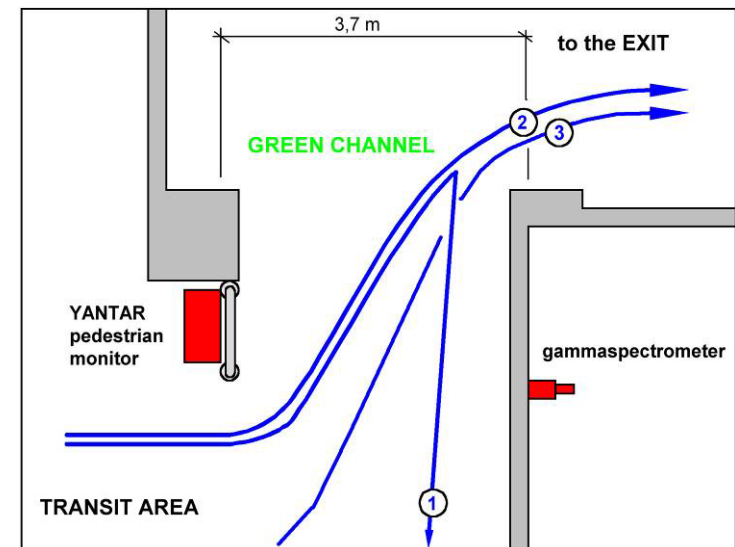


Isotope ID Results VIA, 2005

1 second recording time per spectrum

< 1 second identification time

Medical isotopes		Halflife
	%	
I-131	61	192 hours
Tc-99m	86	6 hours
TI-201	68	73 hours



SRPM at the Entrance Gate of the Vienna International Center (2009)

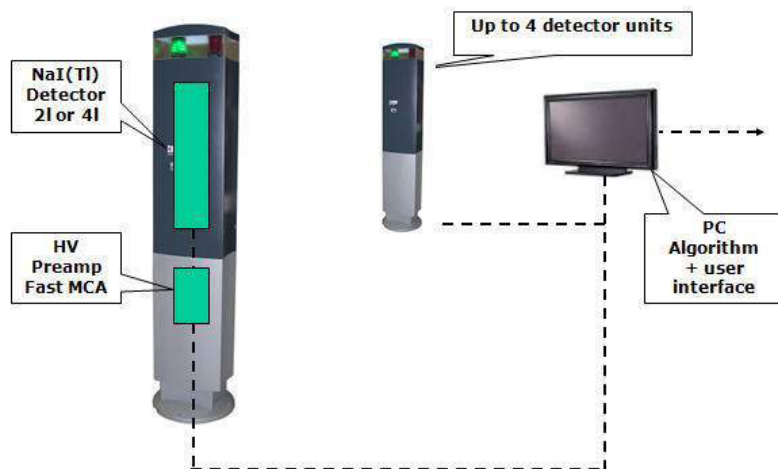


2nd Spectrometric Radiation Portal Monitor Field Test at the Airport Vienna (2009)



December 2008, US DNDO Initiates PaxBag Pilot Programme

- Evaluation of equipment for passenger & luggage monitoring at US airports
- Various companies invited to offer their equipment for evaluation
- A few were selected for further testing



Spectrometric Radiation Search Device (RSD)

- Requirements
 - Carried by a person in a backpack
 - Fully automated data recording and ruggedized design
 - Detection, identification and dose rate in real time
 - Data recording and merging with GPS data, waterfall diagram
 - Battery life for at least 8 hours
- Post processing (off line)
 - GPS mapping
 - Waterfall diagram
 - Expert level isotope ID
- Application areas
 - Security of major public events
 - Radiation monitoring at the „green border“ and in urban areas
 - Search and ID of lost sources

Testing and Development

- In the 90es, first request by Iraq action team, unattended system for use in a car
- 2004 Olympics in Athens, prototype
- 2004 start of development of commercial device, based on available components



Software development,
Starting from 2005, use in
IAEA supported countries:
Radiological security of MPE
Source search
Border control at the Green Border

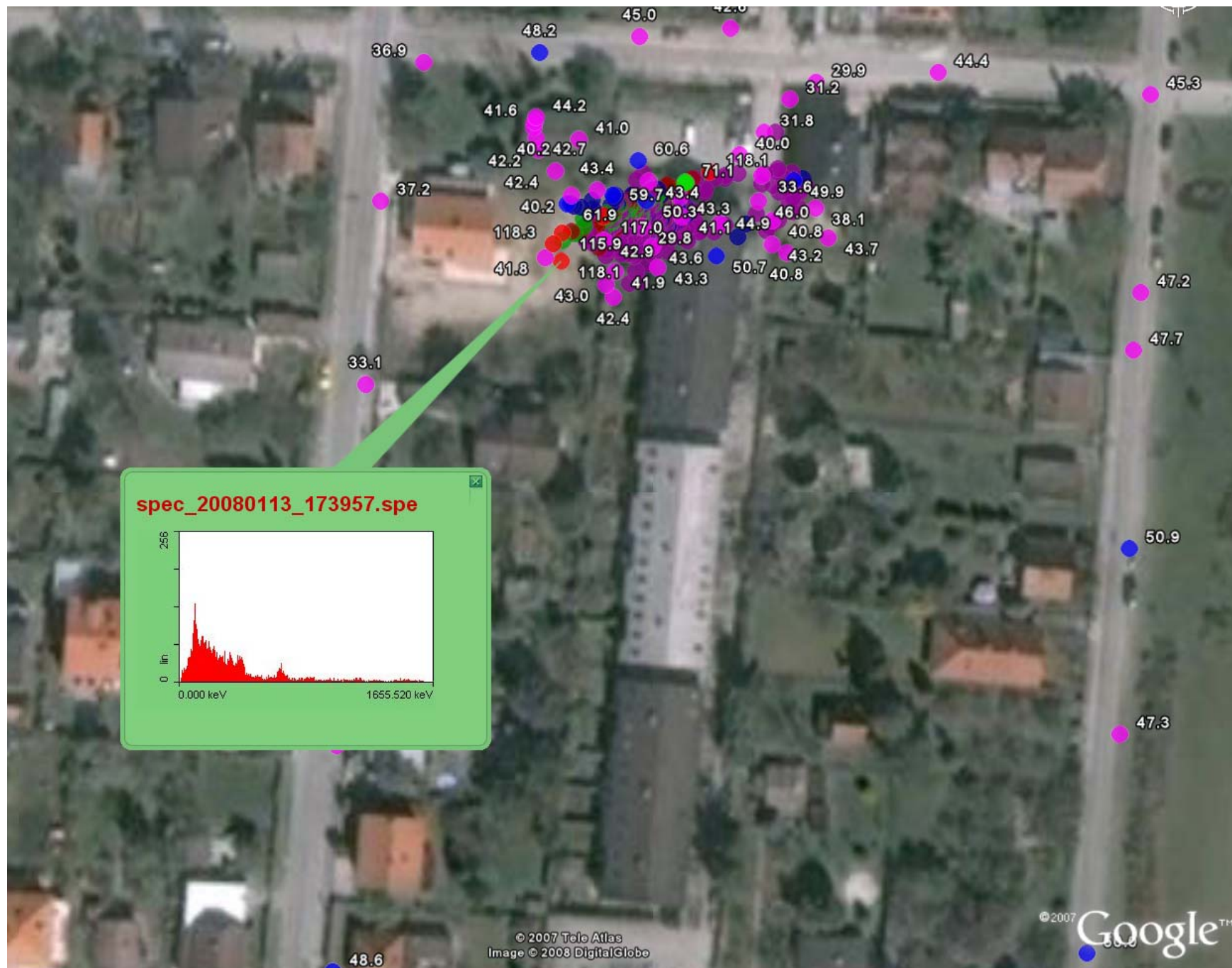
Packaging in a Backpack and use with either Sub notebook or Tablet PC or PDA



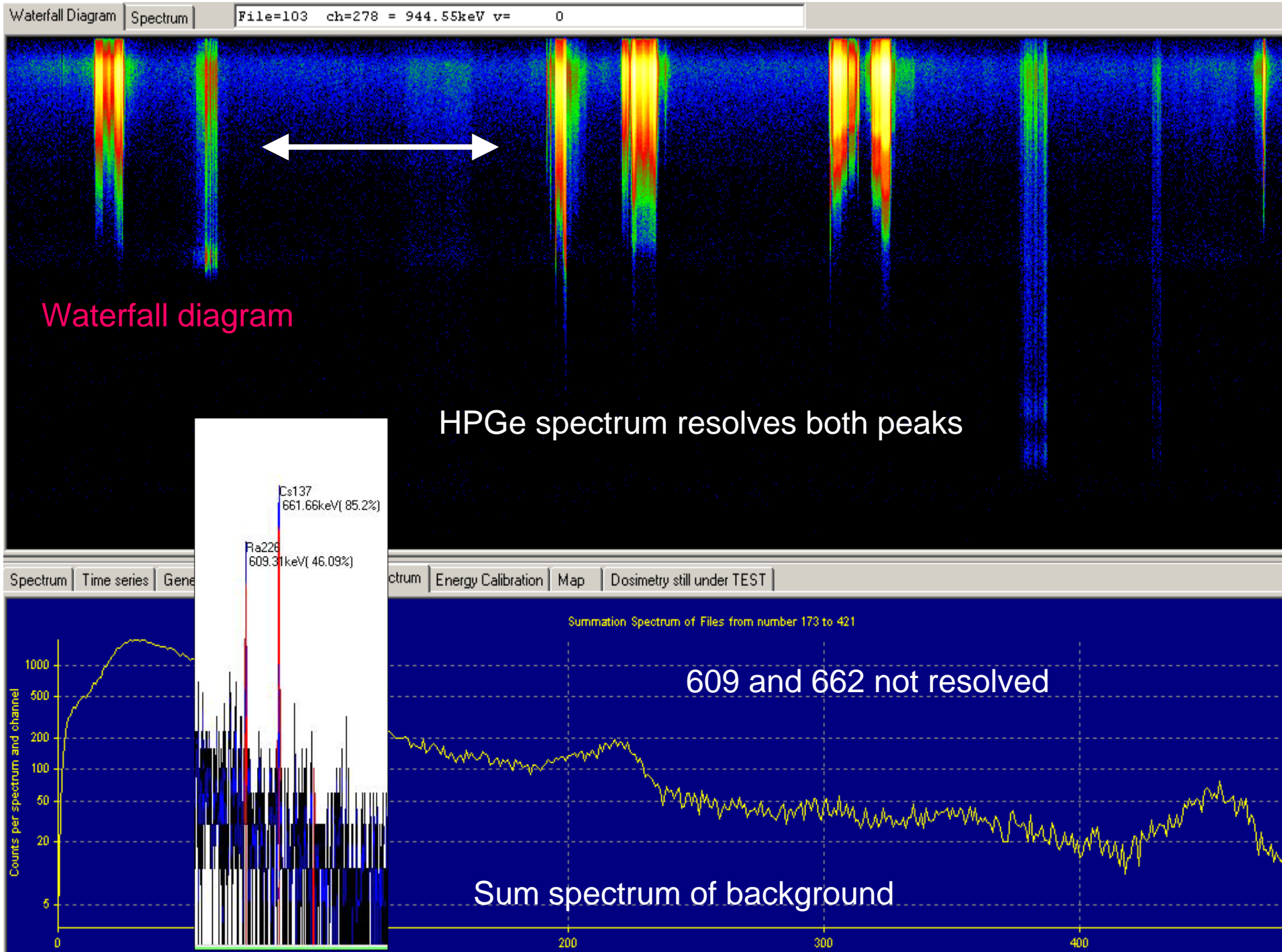
Ruggedized PDA or table computer

Post Processing Software

- Waterfall diagram allows quick overview on 1000nds of spectra to localize events
- Summing of spectra of relevant regions
- Plotting of recorded data within Google Earth, GPS based maps
- Post evaluation of sum spectra with expert level isotope ID software



Test near to Rolf's house with weak Ra-226 sample (wristwatch)



Personal Radiation Detector (PRD) and Spectrometric PRD (SPRD)

- PRDs are the smallest devices
- Use CsI or NaI detectors in gross gamma mode, sometimes additional neutron detector
- Gamma dose rate indication, neutron countrate
- Problems often arise with response to alarm, since RID is often not near to a PRD

Radiation Detectors Inadequate, New York Official Says

The thousands of radiation detectors employed by New York City to identify radioactive material smuggled into the city for terrorism are too sensitive, sapping police resources with false ["innocent"] alarms, a senior official said here yesterday (see GSN, March 8, 2006)...

...as many as 20,000 hand-held radiation detectors carried by police, fire and emergency personnel throughout the city “go off all the time,” he said. “They’re really not that effective in terms of their capability to help us protect, but we are deploying them and we have a standard protocol for response to that,” he said.

...the problem is that medical isotopes in persons and minerals trigger PRDs, without indicating the isotope
The solution may be the use a small spectrometric detector combined with MCA and integrated isotope ID software: **The Spectrometric Personal Radiation Detector.**

Options for Small Spectrometric Gamma Detectors for SPRDs

- Shrinking spectrometric scintillation detectors in size can lead to loss of energy resolution!
- Use of small NaI and CsI, scintillation detectors
 - Lowest cost
 - But moderate resolution
- Better LaBr-3 scintillation detector
 - Better resolution, stability
 - Higher cost
- CZT, room temperature semiconductor detector
 - Best resolution
 - Highest cost
 - Detectors with volume of several ccm available

Spectral Personal Radiation Detectors, Goal=Performance Like RID, but Measure Longer



Rotem
LaBr-3
IEEE 2009



Atomtex, NaI



Thermo/ICx,
US, CZT
Interceptor



ICx US, CZT
Raider



Mirion, NaI



Georadis, NaI

Consequences

- Replacement of gross gamma detectors in
 - Radiation Portal Monitors for pedestrians,
 - Personal Radiation Detectors, and
 - Backpack based Radiation Search Devices ...
- ...by spectrometric systems, which detect AND identify in one step, improve speed and therefore throughput...
- ...leading to an enhanced need for use of spectrometric techniques and spectrum modeling in gamma monitoring at borders

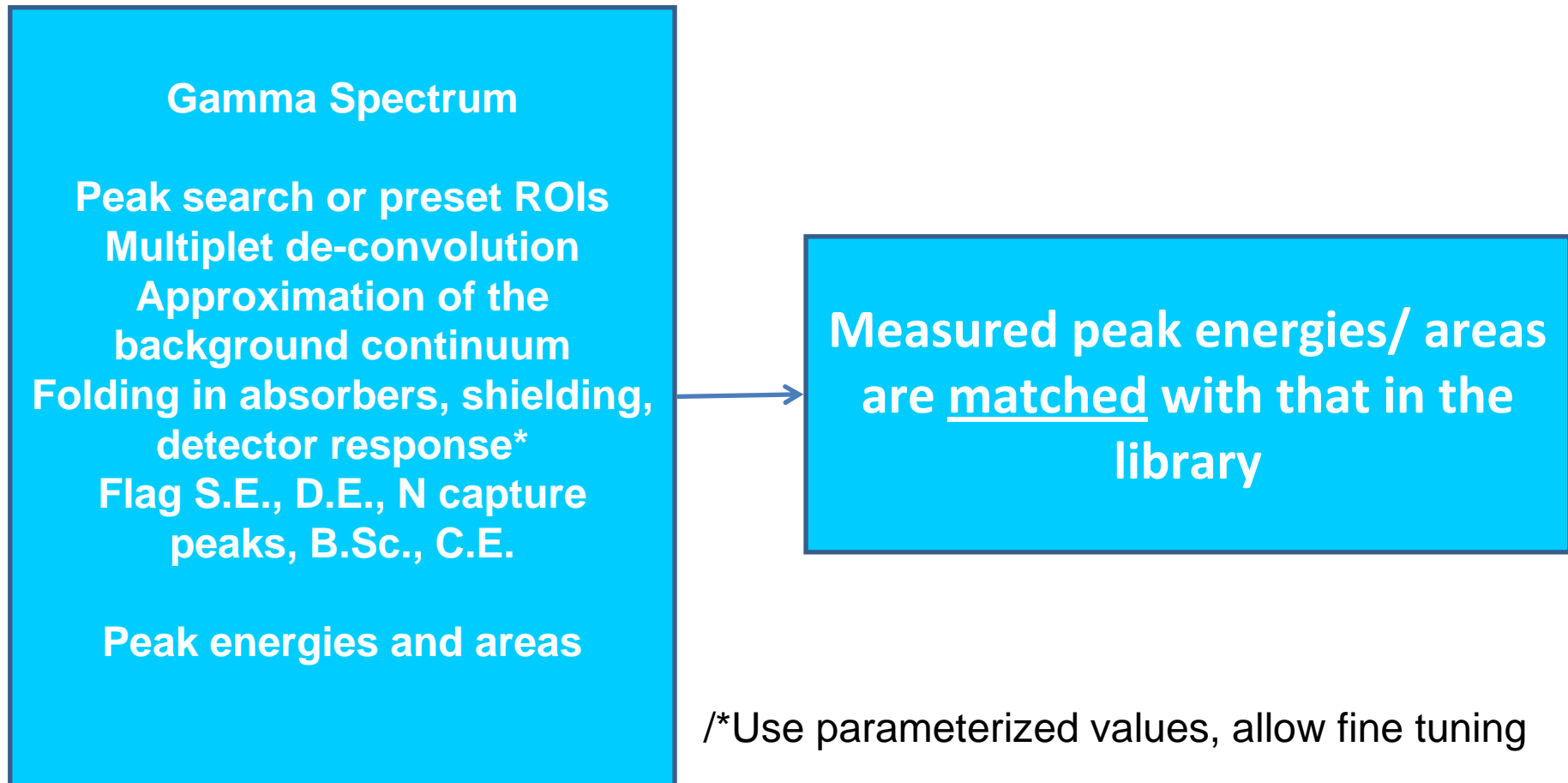
Role of Spectrum Modeling in Isotope ID

- Each group/vendor developing and testing ID methods uses spectrum modeling
 - Development
 - Either at the back end (testing), and/or
 - At the front end (use within the ID software)
- And for the energy linearization of the gamma dose rate estimation

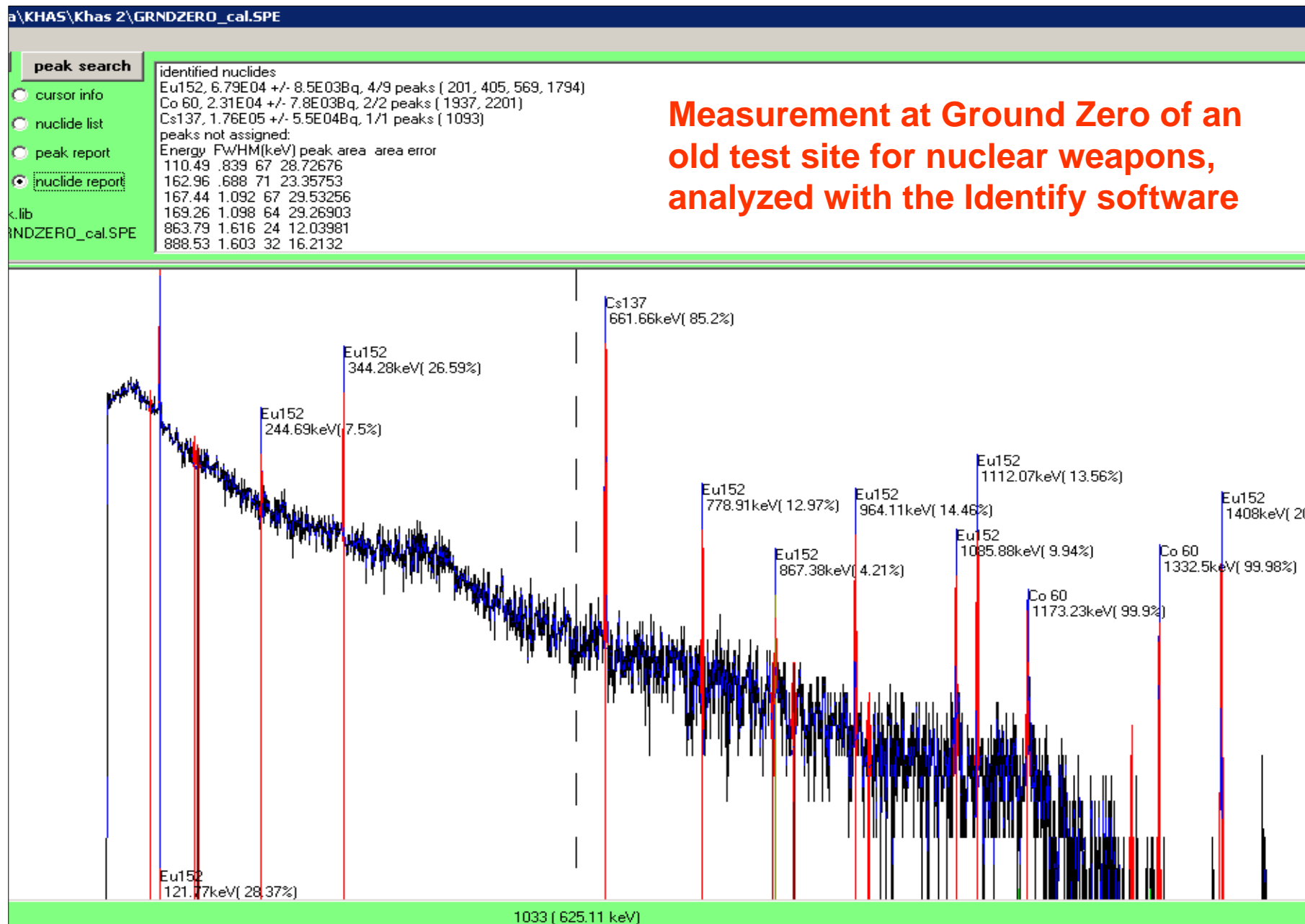
The Role of Spectrum Modeling with ID Software

- Modeling of gamma spectra, for ID methods, using spectrum templates
 - Use of modeled spectra as fixed templates (identiFINDER)
 - Spectrum modeling „on the fly“: Full spectrum analysis (Gadras)
 - Modeling of complex measurement geometries (ASP)
 - Modeling for demonstration and testing
 - Modeling of difficult to get isotopes
 - Dose rate determination over wide energy range with gamma spectrometry

Peak Search Based SW (Example “Identify”)

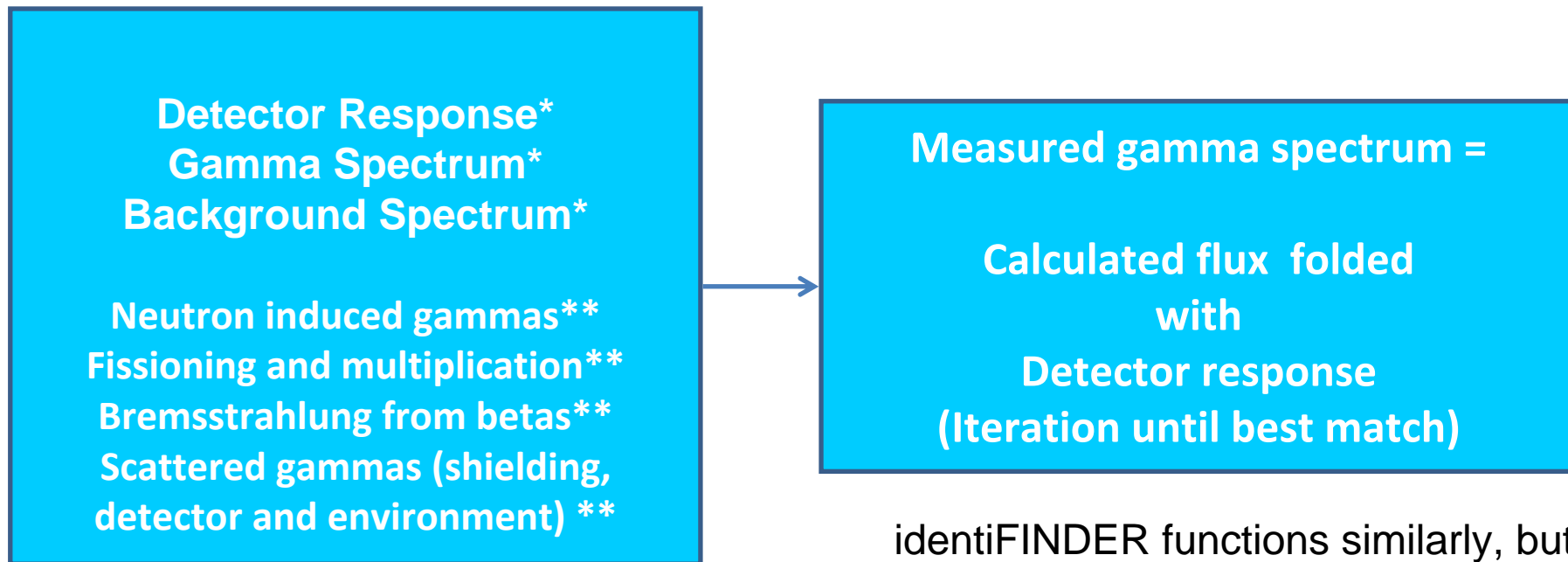


Peak energies and areas must match corresponding values of the radionuclide library, identifying isotopes



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 Compton background is approximated by smooth line

Expert Software - Full Spectrum Analysis (Example “GADRAS”)



/* Measured

/** Obtained by 1D, deterministic transport calculations
optimized for speed (seconds), `on the fly`

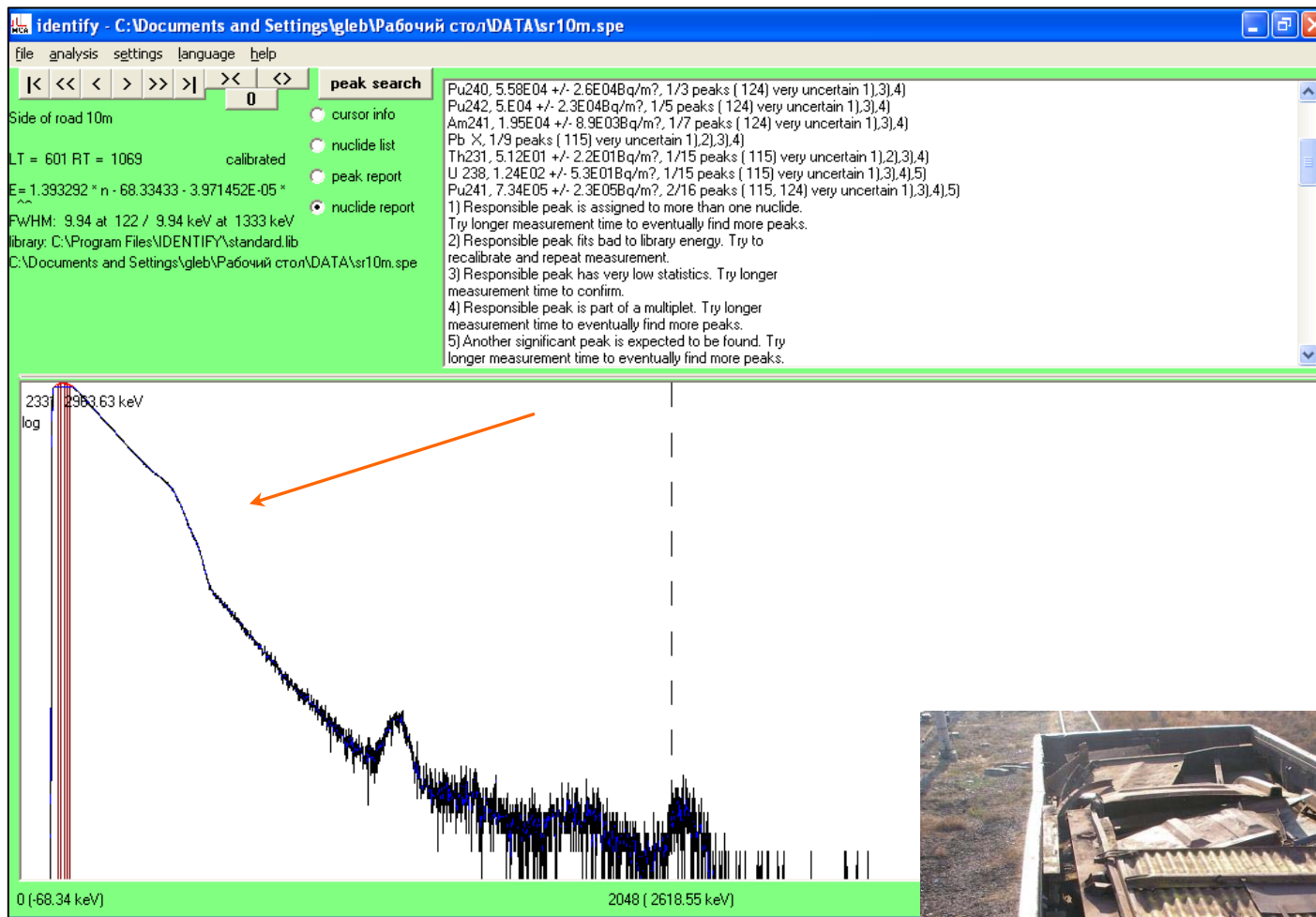
identiFINDER functions similarly, but
spectrum templates prepared before
hand and stored in device memory

**Full spectrum analysis must reproduce/explain all features
of the measured spectrum, identifying isotopes present**

Full Spectrum Analysis Software

- Example GADRAS

- “Full Spectrum Analysis” requires that the shape of the underlying continuum, and gammas due to neutrons (if present), be fully consistent with the nature of the detector and the suggested solution for a given spectrum
- Especially with low resolution spectra, the information *other than peaks* is important -- contains information about shielded and masked, sources and pure beta emitters
- Knowledge of the detector response to both gamma rays and neutrons and of the measurement geometry is required



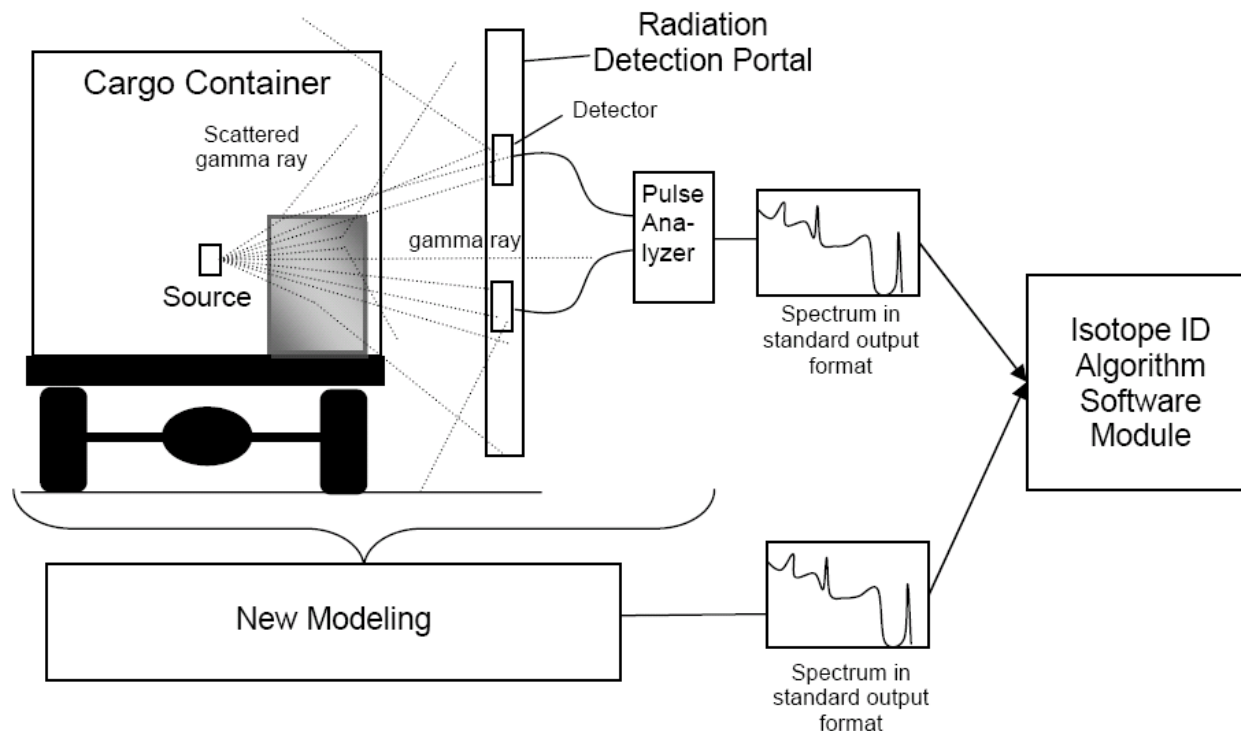
Strong source
buried in scrap,
loaded on a
railway wagon



Broad bump indicates absorbed gammas
which can not be found with peak search
based ID software

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Spectrum Modeling of ASP Proposed by the US National Research Council



Many test geometries could be evaluated and compared with test results

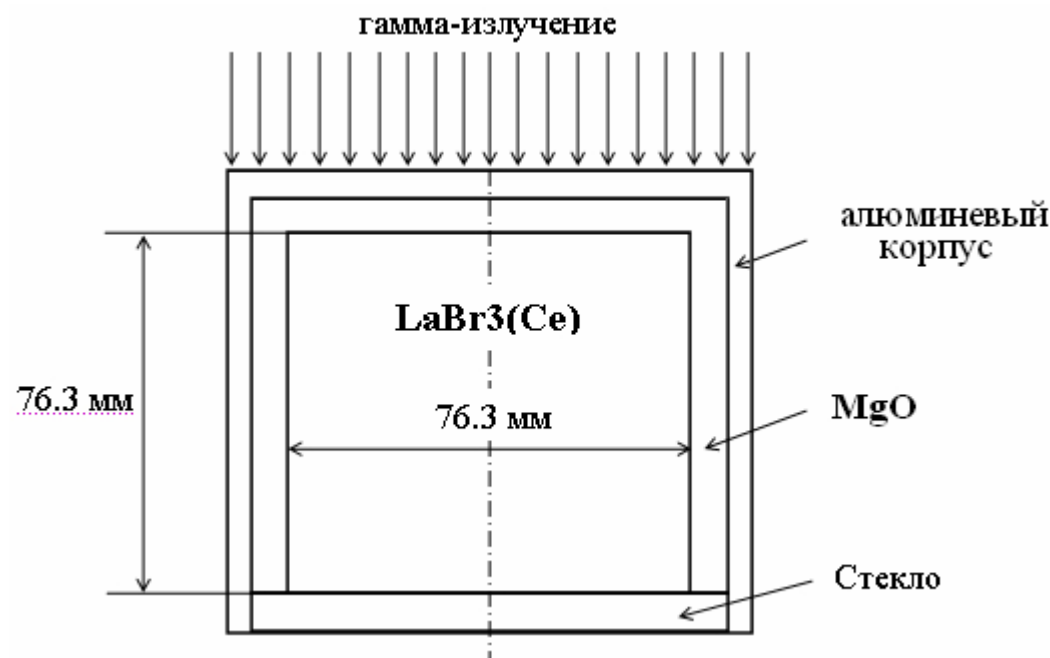
Modeling can be used to select configurations to be used for physical testing

Physical test results can help to validate modeling

Modeling of the whole setup

Linearization of Dose Rate Measurements of 3X3`` LaBr3 Detector

- Detector exposed to a parallel beam of monoenergetic gammas
- Ambient dose rate at the surface = 1 microSv/h
- Gamma spectrum for each of the energies is calculated (modeled)

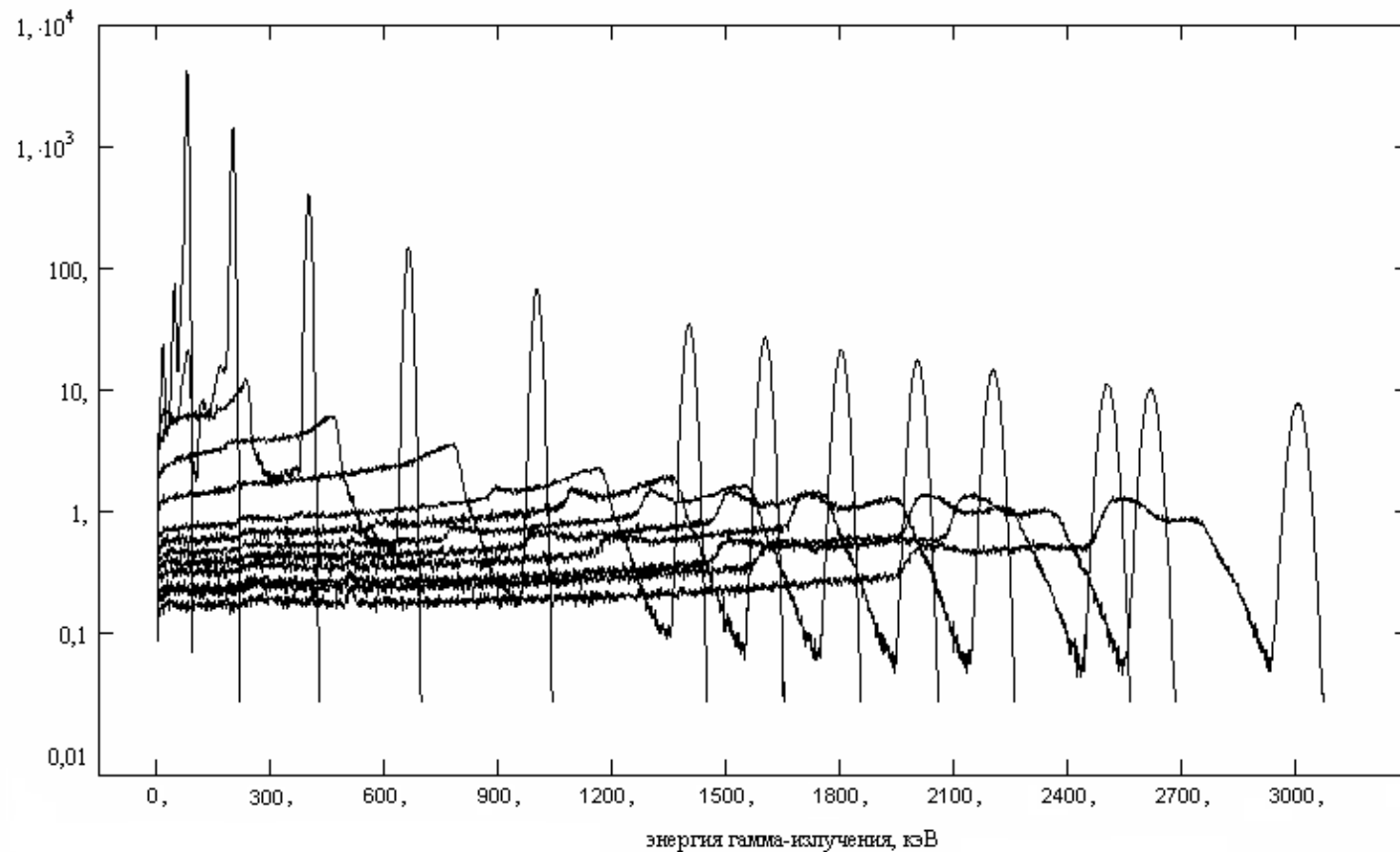


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Calculation of Response to Monoenergetic Gammas with 1 microSv/h each

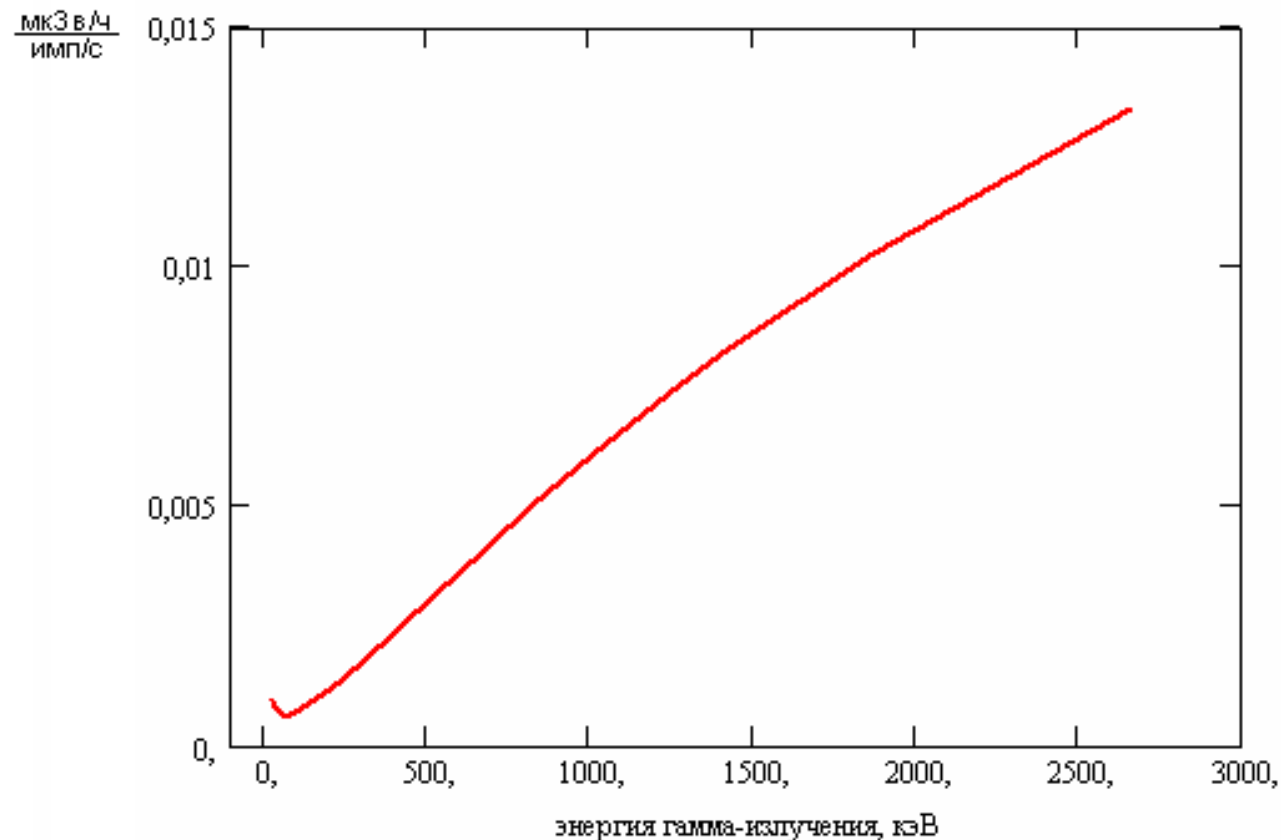
Using the SNEGMONT code the LaBr-3 spectra of monoenergetic gamma spectra in the interval from 10 to 3000 keV were modeled



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Operator for the Transformation Spectrum to Dose Rate

Then a function was calculated, which allows to obtain the
dose rate/countrate value for each energy of a measured gamma spectrum



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Summary, Conclusions

- Spectrometric border monitoring combined with identification is feasible and effective, but comes with a price
- It considerably improves the throughput at checkpoints
- Spectrum modeling is a necessary tool for
 - Development
 - Testing
 - And use with isotope ID methods
- The NUCLEONICA GSG with eMC module becomes an easy to use, Web based tool for EURATOM and IAEA Member States

The Greatest Threat...

IAEA chief says nuclear terrorism poses gravest threat to the world

02/11/2009

The head of the International Atomic Energy Agency, Mohamed El Baradei, warned on Monday that the gravest threat the world faces today is that extremists could get hold of nuclear or radioactive materials.



Mohamed ElBaradei

In his speech to the [General Assembly](#), the agency's chief said in the wake of the September 11 terrorist attacks, the agency initiated a comprehensive programme to combat the risk of nuclear terrorism.

He said he was proud of the speed with which the [IAEA](#) established an effective nuclear security programme providing \$50 million in equipment, training and other assistance to member States in the last three years.

Abbreviations

•	RDD	Radiological Dispersion Device
•	RED	Radiation Exposure Device
•	ID	Identification
•	RID	Radionuclide Identification Device
•	ASP	Advanced Spectroscopic Portal
•	RPM	Radiation Portal Monitor
•	SRPM	Spectrometric Radiation Portal Monitor (for pedestrians)
•	PRD	Personal Radiation Detectors
•	SPRD	Spectrometric Personal Radiation Detector
•	RSD	Radiation Search Device
•	PRS	Portable Radiation Scanner
•	HPRDS	Human Portable Radiation Detection System
•	DHS	Department of Homeland Security (US)
•	DNDO	Domestic Nuclear Detection Office (US)
•	BCP	Border Crossing Point
•	FLO	Front Line Officer
•	NaI	Sodium Iodide Detector
•	HPGe	High Purity Germanium Detector
•	GAO	Government Accountability Office (US)
•	GPS	Global Positioning System
•	MPE	Major Public Event
•	eMC	easy Monte Carlo Module
•	GSG	Gamma Spectrum Generator

If questions:
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